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# Effects of Detention Period and Sand-Based Surface Flow Constructed Wetland in Kitchen Wastewater Treatment using Phragmites Australis (Common Reed) as Macrophyte

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**Abstract**
A greenhouse laboratory-scale experiment was conducted at the Department of Civil Engineering, Ladoke Akintola University of Technology (LAUTECH) Ogbomoso, Nigeria in May 2013 to demonstrate the performance of free water surface-flow sand- based constructed wetland, prepared with locally available plants, specifically common reed (Phragmites australis), as a viable low-cost efficient treatment option for domestic wastewater from kitchen. The nutrient removal and performance evaluation of the constructed wetland in treatment of kitchen wastewater was investigated. Treatment efficiency was evaluated during the 10-day retention period, and results indicated that the nutrients reduction corresponds to a longer retention time in wetland beds. There is a remarkable reduction in B.O.D (38.2-100%), hardness (100%), turbidity (55.2-77.2%), Nitrate (66.7-100%), zinc, ORP (45.0-79.1%), Sulphite (24-100%) sulphate (100%), TSS (55.2-82.3%) and little reduction in TDS (6.93-40%) and also there was increase in pH (31.7-45.6%), Magnessium (16.7-50%), Iron (50-75%), calcium ( 16.7-50%) The final effluent was found to be suitable for non-drinking purposes like crop irrigation, keeping aquatic animals and direct discharge into a receiving water body as the concentrations were well below allowable limits.The treatment system was found to be economical, as the cost of construction only was involved and maintenance cost very minimal. It was environmentally friendly as it was free from offensive odour and insect invasion. A pilot scale constructed wetland is recommended for further research works.
**Keywords:** Constructed wetland, Kitchen wastewater, Nutrient removal, Retention period, Phragmites australis

## 1. Introduction

In recent years, increasing production and disposal of wastewater have caused an accelerated pollution of receiving water bodies. Hence, to reduce the harmful impact of the wastewater discharge, there is the need to remove the main nutrients such as nitrogen and phosphorus as well as the organic content of the wastewater prior to disposal. This can be effectively achieved by the conventional treatment technology, but the working expenses and energy requirements of such treatment systems are rather high and in many cases hinder by economic constraints which often leads to the desertion of such various treatment plants in the country (Nigeria) due to lack of funding and consequently maintenance on the part of the responsible agency. However, several investigations have shown that wetlands may act as efficient water purification systems and nutrient sinks (Dolan *et al.,* 1981; Brix, 1989 and 1993; Vinita *et al.*, 2008; Jun-jun Chang *et al.,* 2012).

Constructed wetlands are artificial wastewater treatment system consisting of shallow (usually less than 1 m deep) ponds or channels, which have been planted with aquatic plants, and rely upon natural microbial, biological, physical and chemical processes to treat wastewater (Sandeep *et al.,* 2005). These systems of wastewater treatment offer several potential advantages as compared to conventional treatment system, this include; simple construction (can be constructed with local materials), require less skill to operate and maintain, process stability under varying environmental conditions, Utilization of natural processes, and lower construction, operation and maintenance costs. There are two basic types of constructed wetland namely; free water surface flow constructed wetland in which the flow of water is above the sediment surface, and subsurface flow constructed wetland in which the flow of water is primarily below the sediment surface.

These systems use wetland plants, soils and their associated microorganisms to remove contaminants from wastewater (Borkar and Mahatme, 2011; Baskar *et al.*, 2009). The pollutant removal mechanisms in a constructed wetland plant comprise several physical, chemical, biological and biochemical processes (Brix, 1993; UN-HABITAT, 2008), and this include; sedimentation, filtration, aerobic and anaerobic microbial degradation, plant uptake, soil sorption, precipitation and so on.

Reeds are coarse grasses growing in wet places. Reed bed is one of the natural and cheap methods of treating domestic, industrial and agricultural liquid wastes. Reed bed is considered as an effective and reliable secondary and tertiary treatment method where land area is not a major constraint (Wood and Hensman, 1988).

Generally reed bed is made in shallow pits, installed with a drain pipe in a bed of pieces of lime stones and filled up with pebbles and graded sand (Crites, 1994). Wastewater treatment plants neutralize and deactivate the chemicals found in the water. They work by relying on the bacteria that is found in our colons, which eats away the nitrates, phosphates and organic matter that is present. These plants can be expensive to build and operate for many governments, but there are cheaper alternative which rely on nature to do most of the work. This is done by rebuilding wetlands, because the plants and bacteria found in the wetlands will do the same thing that bacteria in standard sewage treatment will do. This helps environment in two ways: restoring wetlands and treating human wastewater before it pollutes the natural waterways. Zeina, et al. (2000). The United States were marginally successful, and it has not been utilized in recent years in this country. Kickuth proposed the use of cohesive soils instead of sand or gravel; the vegetation of preference was *Phragmites* and the design flow path was horizontal through the soil media. Kickuth's theory suggested that the growth, development and death of the plant roots and rhizomes would open up flow channels, to a depth of about 0.6 m (2 ft) in the cohesive soil, so that the hydraulic conductivity of a clay-like soil would gradually be converted to the equivalent of a sandy soil. This would permit flow through the media at reasonable rates and would also take advantage of the adsorptive capacity of the soil for phosphorus and other materials. Very effective removal of BOD5 TSS, nitrogen, phosphorus, and more complex organics was claimed. As a result, by 1990 about 500 of these "reed bed" or "root zone" systems had been constructed in Germany, Denmark, Austria, and Switzerland. The types of systems in operation include on-site single family units as well as larger systems treating municipal and industrial wastewaters. Many of the -early systems were $BOD_5$ removal**.** The physical removal of $BOD_5$ is believed to occur rapidly through settling and entrapment of particulate matter in the void spaces in the gravel or rock media. Soluble $BOD_5$ is removed by the microbial growth on the media surfaces and attached to the plant roots and rhizomes penetrating the bed. Some oxygen is believed to be available at micro sites on the surfaces of the plant roots, but the remainder of the bed can be expected to be anaerobic. Compared to other forms of wastewater treatment, both SF and FWS wetland systems are unique in that $BOD_5$ is actually produced within the system due to the decomposition of plant litter and other naturally occurring organic materials. As a result, the systems can never achieve complete $BOD_5$ removal and a residual $BOD_5$ from 2 to 7 mg/L is typically present in the effluent.

Most of the constructed wetlands in the U.S utilize one or more of the plant species, about 40 percent of the operational SF systems use only *Scripus. Phragmites* is the most widely used species in the European systems. A number of systems in the Gulf States also used a number of flowering plants for aesthetic reasons. These soft tissue plants decompose very rapidly and can affect water quality in the effluent. Many locations adopted a routine fall harvest to remove these plants before they died or suffered frost damage. There have been some attempts to create a plant diversity similar to that present in a natural marsh; this approach is more expensive and the intended diversity can be difficult to maintain.

The *Phragmites* used in many European systems offer several advantages for a low maintenance treatment system. They will grow and spread faster than bulrush; their roots should go deeper than cattails; and they are not a food source for muskrats and nutria which have been a problem for cattail and bulrush wetlands. However, the habitat values for a *Phragmites* system are probably less than for other plant species. A number of systems in the Gulf States utilize an annual harvest, regardless of the plant species used. In contrast, routine annual harvesting is not practiced in Europe or at most other systems in the U.S. It may be useful to remove undesirable weeds during the early part of the growing season for the first few years of operation. Flooding of the bed surface after the initial planting can help reduce weed infestation. A routine annual harvest of the entire system provides minimal benefits and is not recommended. It is also suggested that the use of soft tissue flowering plants be avoided and thereby eliminate the need for their annual harvest and related maintenance.

Water level management in the SF bed is not only helpful for weed control, but can also be used to induce deeper root penetration. Based on experience in Europe, it is claimed that if the water level in the bed is gradually lowered in the fall of each year the roots will penetrate to greater depths. A three year period is considered necessary for *Phragmites* roots to reach their 0.6 m potential depth. Although this approach has not been tried in the U.S. it should be successful, but it may have to be too small scale on-site systems. The subsurface flow (SF) constructed wetland concept can offer high performance levels for $BOD_5$ and TSS at relatively low costs for construction and operation and maintenance. It is particularly well suited for small to moderate sized installations.

The subsurface flow (SF) constructed wetland concept can offer high performance levels for $BOD_5$ and TSS at relatively low costs for construction and operation and maintenance. It is particularly well suited for small to moderate sized installations. Wetland ecosystems, including constructed wetlands for wastewater treatment, are vegetated by wetland plants. The ability of wetlands to transform and store organic matter and nutrients has resulted in a widespread use of wetland for wastewater treatment worldwide. Wetland plants are an important component of wetlands, and the plants have several roles in relation to the wastewater treatment processes.

The present project attempts to provide an overview and summarize the role of the wetland plants in constructed wetlands. The presence of vegetation in wetlands distributes and reduces the current velocities of the water. This creates better conditions for sedimentation of suspended solids, reduces the risk of erosion and re-suspension, and increases the contact time between the water and the plant surface areas. The macrophytes are also important for stabilizing the soil surface in treatment wetlands, as their dense root systems impede the formation of erosion channels. In vertical flow systems the presence of the macrophytes, together with an intermittent loading regime, helps to prevent clogging of the medium. The movements of the plants as a consequence of wind, etc., keep the surface open, and the growth of roots within the filter medium helps to decompose organic matter and prevents clogging Oxygen release rates from roots depend on the internal oxygen concentration, the oxygen demand of the surrounding medium and the permeability of the root-walls

Wetland plants conserve internal oxygen because of submerized and lignified layers in the hypodermis and outer cortex. These stop radial leakage outward, allowing more oxygen to reach the apical meristem. Thus, wetland plants attempt to minimize their oxygen losses to the rhizosphere. Wetland plants do, however, leak oxygen from their roots. Rates of oxygen leakage are generally highest in the sub-apical region of roots and decrease with distance from the root-apex. The oxygen leakage at the root-tips serves to oxidize and detoxify potentially harmful reducing substances in the rhizosphere. Species possessing an internal convective through flow ventilation system have higher internal oxygen concentrations in the rhizomes and roots than species relying exclusively on diffusive transfer of oxygen (Armstrong and Armstrong, 1988), and the convective through flow of gas significantly increases the root length that can be aerated, compared to the length by diffusion alone (Brix, 1987).

Wetland plants with a convective through flow mechanism therefore have the potential to release more oxygen from their roots compared to species without convective through flow. Studies on individual roots have been done using oxygen micro-electrodes to measure radial oxygen losses in oxygen-depleted solutions (Laan et al., 1989). The oxygen release rates obtained by this technique vary from less than 10 to 160mg oxygen cm-2 root surface min-1 depending on species. Oxygen release from fine laterals at the base of roots can be significant, but generally, no release of oxygen from old root sand rhizomes is detected (Armstrong and Armstrong, 1988). The non homogeneity of Studies on individual roots has been done using oxygen micro-electrodes to measure radial oxygen losses in oxygen-depleted solutions. The oxygen release rates obtained by this technique vary from less than 10 to 160 mg oxygen cm-2 root surface min-1 depending on species. Oxygen release from fine laterals at the base of roots can be significant, but generally, no release of oxygen from old roots and rhizomes is detected (Armstrong and Armstrong, 1988).

## 2. Material and Methods

### 2.1 *Study Site*

The laboratory scale free water surface flow constructed wetland was set-up at the department of Civil Engineering Ladoke Akintola University of Technology which was established in September 1990 and located in the agrarian town of Ogbomoso in Oyo state which lies between latitude 8$^{o}$ 08' 01''N and longitude 4$^{o}$ 14' 48''E. The town is characterized by an average daily temperature of between 25$^{o}$ and 35$^{o}$ almost throughout the year.

### 2.2 *Experimental Setup*

The wetland cell which was made of a transparent plastic was 0.9 m deep, 0.6 m long and 0.6 m wide to give a total volume of 0.324 $m^3$ (Fig. 1). The outlet is a plastic tap fitted to the bottom side of the basin while the inlet is excluded as water will be fed into the wetland system manually. The basin was lined to prevent leakages, and encased with a wooden frame to give it the required rigidity and support to prevent outburst of the plastic basin (Fig. 2). Furthermore, the inlet of the tap was covered with screen during substrate filling to prevent the passage of sand with the water, the substrates were properly washed to eliminate the undesired particles and dust, and sieved to obtain the desired grain size (granite 13.5 mm and 8mm, gutter sand and humus < 2mm), and the basin was filled as follow:

The first layer of 100mm depth consisted of granite of 13.5 mm size.
The second layer of 150mm depth consisted of granite of 8mm size.
The third layer of 200mm depth consisted of washed gutter sand.
The fourth layer of 150mm depth consisted of humus soil to support plant growth.
300mm free board was provided.

### 2.3 *Planting of the Vegetation*

Live plant transplant was employed for this setup, six rhizome stocks of Phragmites australis plants was planted at the depth of planting was 10 cm below the surface of the humus soil and the plant was cultured in the setup with tap water by wetting it manually every day . After a period of eight months (July 2013 to March 2014), the six Phragmites australis plants that were planted initially have multiply to cover the entire setup forming a thick vegetation with profuse roots (Fig. 3). The plant growth was also monitored and the plant was found to have a rapid rate of growth with an average growth rate of 0.31 meter per week.

### 2.4 *Wetland Operation*

2.4.1 *Draining of the Setup:* - All the water present in the setup was drained two days before the introduction of the wastewater by keeping the outlet widely open. This is necessary to avoid the dilution of the wastewater by the fresh water used in nurturing the plant and therefore eliminate error during analysis.

2.4.2 *Wastewater Collection* :- The wastewater used for this research work was collected from Alata milk and honey kitchen an eatery located Under-G area, nearby University Campus in Ogbomoso along Ilorin road with the aid of six 25 liters kegs to make the total volume of the waste water collected 150 liters.

2.4.3 *Pretreatment and Introduction of the Wastewater into the Setup:* - A total volume of 75 liters of wastewater was screened using a 75µm sieve and introduce into the setup manually from the open roof at top of the basin on 17th of March 2014.

Figure 1: Wetland Unit

Figure 2: Laying granular beds in the container.

Figure 3: Setup at initial stage

Figure 4: Setup after seven months

*2.5 Sample Collection and Qualitative analysis*

75cl sample each was collected from the setup for detention time of 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 days respectively including that of the raw waste water, and qualitative analysis carried out according to APHA standard on each of the sample collected to determine the effect of detention period on the wastewater.

The parameters tested for are; Colour, pH and odour, Temperature, Turbidity, Conductivity, Dissolved Oxygen (DO), Biochemical Oxygen Demand ($BOD_{5,20}$), Magnesium (Mg), Chloride ($Cl^-$), Sulphide ($SO_4$) and Nitrate ($NO_3$).

## 3. Results and Discussion

The results of the Physico-chemical analyses carried out on the samples daily for a retention time of ten (10) days were presented are as shown in Tables 1 below:

*3.1 pH*

The pH ranged from 5.50 to 6.91. Generally, the obtained pH values fall within the World Health Organization standards of 6.5 to 8.5 and the water quality ranges 6.5 to 8.5 for drinking water according to NAFDAC range.

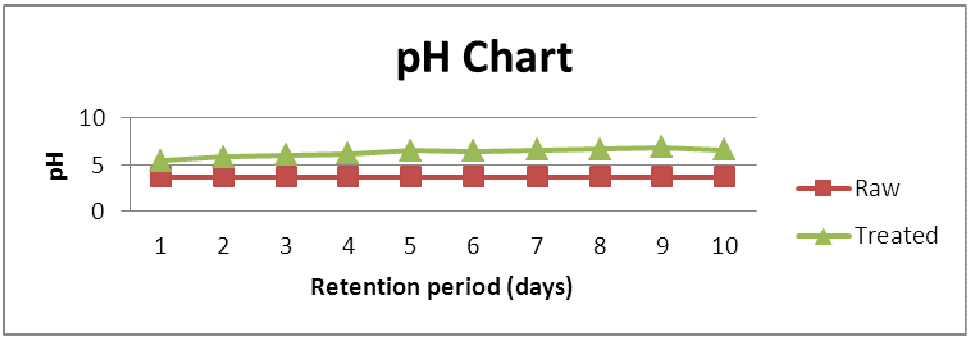


Figure 5: Chart of pH showing treated water against raw water with retention days

### 3.2 *Temperature*

The temperature profile of the treated water sample varies significantly and ranged from 24.8 to 30.1 °C. 40$^0$C is the limit given by WHO while 20-35$^0$C is the recommended limit for no risk according to the NER standard for discharge effluent into water bodies. Based on these guidelines, the temperature of the effluent does not appear to pose any threat to the homeostatic balance of the receiving water bodies. It will however reduce solubility of oxygen and amplified odour due to anaerobic reaction.

Table 1- Statistical Analysis of the parameters in wastewater treated against the retention time.

| **Parameters** | **Retention Time (days)** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
| **Turbidity (FTU)** | **491** | **220** | **195** | **180** | **112** | **152** | **160** | **177** | **187** | **173** | **87** |
| **Temperature ($^o$c)** | **27.7** | **27.9** | **27.2** | **26.5** | **26.6** | **26.4** | **30.1** | **30.0** | **27.3** | **24.8** | **25.5** |
| **Hardness** | **0.53** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
| **pH** | **3.76** | **5.50** | **5.89** | **6.14** | **6.25** | **6.60** | **6.55** | **6.65** | **6.74** | **6.91** | **6.66** |
| **Conductivity (µs)** | **18.8** | **31.2** | **30.3** | **28.2** | **28.3** | **26.9** | **27.8** | **26.2** | **25.8** | **23.3** | **20.0** |
| **Sulphite (mg/L)** | **10** | **8** | **8** | **4** | **4** | **4** | **6** | **4** | **2** | **2** | **2** |
| **Magnesium (mg/L)** | **36.45** | **43.74** | **72.9** | **65.61** | **58.32** | **58.32** | **72.9** | **72.9** | **43.74** | **43.74** | **58.32** |
| **Nitrate (mg/L)** | **30** | **10** | **10** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
| **Chloride** | **1155** | **600** | **680** | **670** | **640** | **650** | **580** | **670** | **730** | **650** | **660** |
| **Iron (mg/L)** | **1** | **2** | **2** | **3** | **3** | **3** | **3** | **4** | **4** | **4** | **4** |
| **Zinc (mg/L)** | **0** | **1.2** | **2** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
| **Calcium** | **59.98** | **71.98** | **119.96** | **107.97** | **95.971** | **95.971** | **119.96** | **119.96** | **71.98** | **71.98** | **95.97** |
| **Sulphate (mg/L)** | **1.084** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
| **Oxygen Reduction Potential(ORP) mV)** | **211** | **116** | **98** | **85** | **79** | **61** | **63** | **58** | **53** | **44** | **56** |
| **DO (ppm)** | **109** | **81.2** | **85** | **68.1** | **52.0** | **61.6** | **47.1** | **48.2** | **42.8** | **39.9** | **74.3** |
| **$BOD_5$ @ 20$^{oc}$ (mg/L)** | **73.9** | **42.2** | **45.7** | **30.7** | **6.3** | **11.7** | **10.7** | **1.6** | **0** | **0** | **5.4** |
| **TDS (mg/L)** | **12.60** | **20.90** | **20.30** | **18.89** | **18.96** | **18.02** | **18.63** | **17.55** | **17.29** | **15.61** | **13.53** |
| **TSS (mg/L)** | **1718.5** | **770** | **682.5** | **630** | **392** | **532** | **560** | **619.5** | **654.5** | **605.6** | **304.5** |

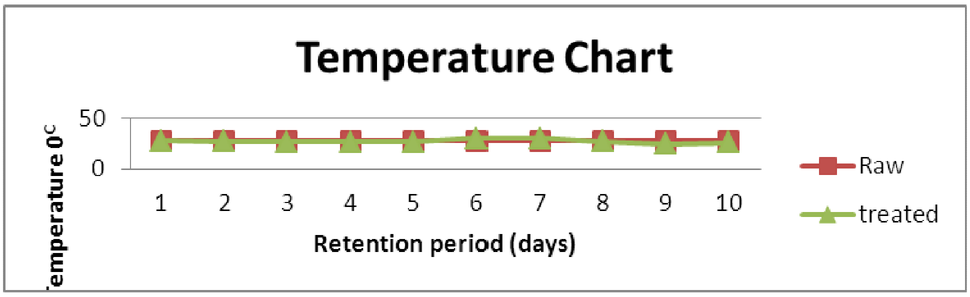


Figure 6: Chart of Temperature showing treated water against raw water with retention days

### 3.3 *Turbidity*

The turbidity profile varies significantly throughout the study period and ranged from 87 to 220 FTU. The turbidity values obtained from the treated water is higher than WHO standard of 5 NTU (WHO, 2004). These values are grossly exceeded in the water samples and it disqualifies the water from direct domestic use. But it meets the national Environment (Discharge of effluent into water or land) regulations of 300NTU. Also, the excessive turbidity in water can cause problem with water purification processes such as flocculation and filtration, which may increase treatment cost (DWAF, 1998).

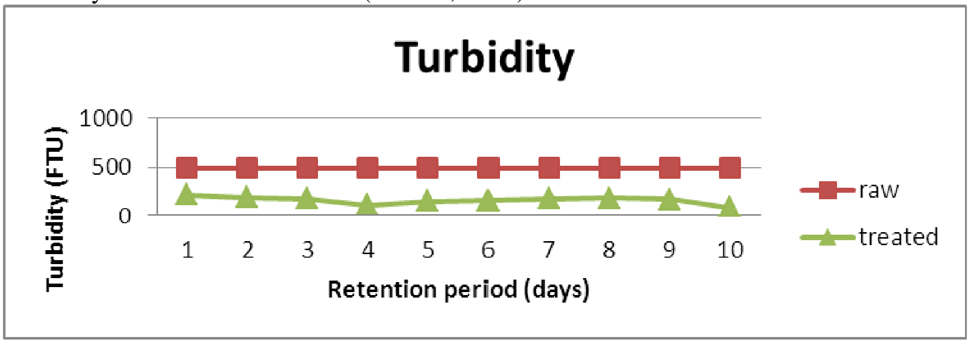


Figure 7: Chart of Turbidity showing treated water against raw water with retention days

Figure 8: Appearance of the Water Before and After Treatment

*3.4 Dissolved Oxygen*

The concentration of total dissolved oxygen ranges from 85– 39.9mg/l which is much lesser than the maximum permissible limit of 500mg/l of WHO and NAFDAC. This could be attributed to the presence of degradable organic matter which resulted in a tendency to be more oxygen demanding. The DO values from this study fell in the range of the recommended standard.

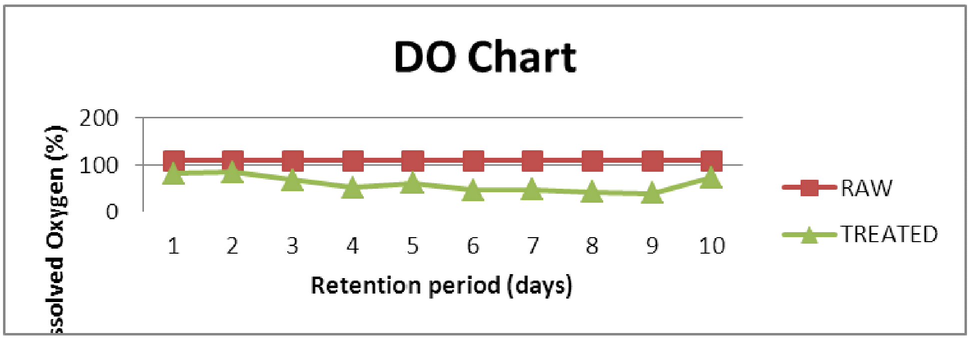


Figure 9: Chart of Dissolved Oxygen showing treated water against raw water with retention days

*3.5 Electrical Conductivity*

The electrical conductivities of the water samples generally varied significantly and ranged from 20.2 to31.2µs/cm throughout the period of study. Higher conductivities were observed in the treated sample. Electrical conductivity is a useful indicator of mineralization and salinity or total salt in a water sample. The FEPA acceptable limit for conductivity in domestic water supply is 70µs/cm (DWAF, 1996a). Thus, the water is suitable for direct domestic use.

 

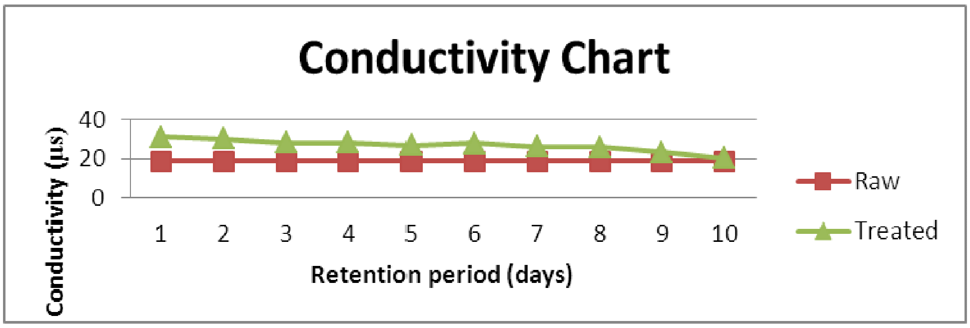


Figure 10: Chart of Conductivity showing treated water against raw water with retention days

*3.6 Total Hardness*

The ionic species in the water causing the precipitation was later found to be primarily calcium and magnesium. It is also known that certain other ion species, such as iron, zinc and manganese, contribute to the overall water hardness. The measure and subsequent control of water hardness is essential to prevent scaling and clogging in water pipes. From this study we discovered the use of common reed is so efficient in the removal of hardness.

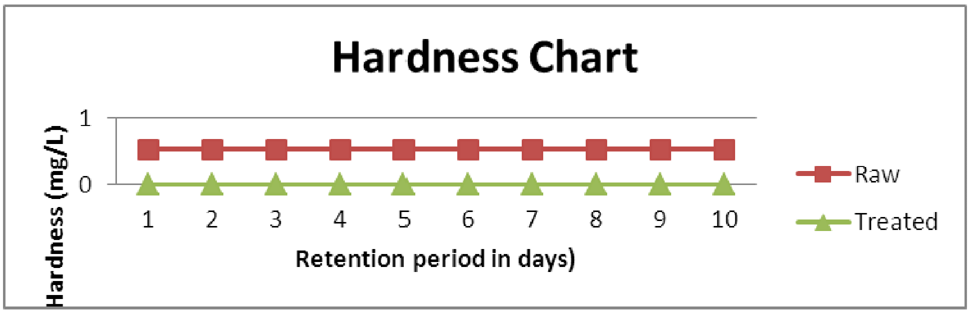


Figure 11: Chart of Hardness showing treated water against raw water with retention days

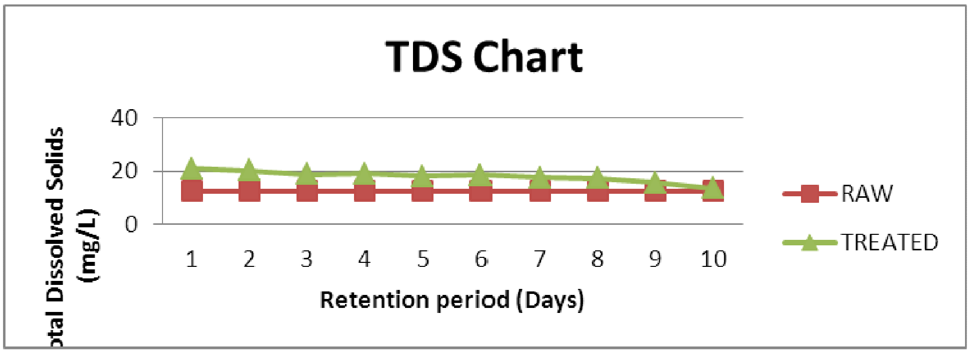


Figure 12: Chart of Total Dissolved Solids showing treated water against raw water with retention days

*3.7 Total Dissolved Solid*

The maximum permissible limit standardized for total dissolved solids by the World Health Organization is 1000mg/l while the concentration of total dissolved solids in sampled waste water treated ranges from 13.53 – 20.90mg/l, which is lower than the maximum permissible limit. Water with higher solids content often has a laxative and sometimes the reverse effect upon people whose bodies are not adjusted to them. High concentration of dissolved solids (about 3000mg/l) may also produce distress in livestock. Sources of total dissolved solids in groundwater are livestock waste, septic system, landfills, nature of soil, hazardous waste landfills, dissolved minerals, iron and manganese.

*3.8 Total Suspended Solids*

These involve settleable solids. The turbidity introduced by these solids prohibits photosynthesis, and does decompose leaves of aquatic macrophytes and algae. TSS was gotten with a relationship with turbidly. TSS equals 3.5 x Turbidity. The value of TSS ranged between 580 to 730. Also, from the analysis, common reed was able to reduce the concentration of Total suspended Solid by 55.2 – 82.3%. The TSS value for the raw water was more than the treated water samples.

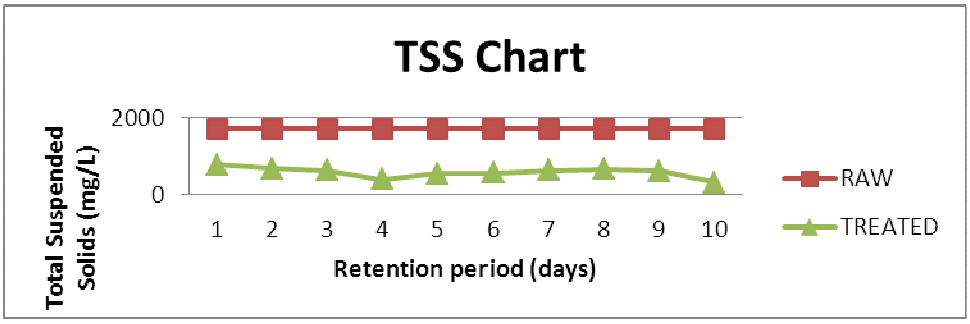


Figure13: Chart of Total Suspended Solids showing treated water against raw water with retention days

### *3.9 Sulphite*

In industrial applications, a sulfite concentration of approximately 20 mg/L must be maintained to prevent pitting and oxidation of metal components as in boiler feed and effluent waters. A high level of sulfite results in a lowered pH, thus promoting corrosion. The monitoring of sulfite is important in environmental control. Sulfite ions are toxic to aquatic life forms and their ability to remove dissolved oxygen in water will destroy the delicate balance of ecology of lakes, rivers and ponds.

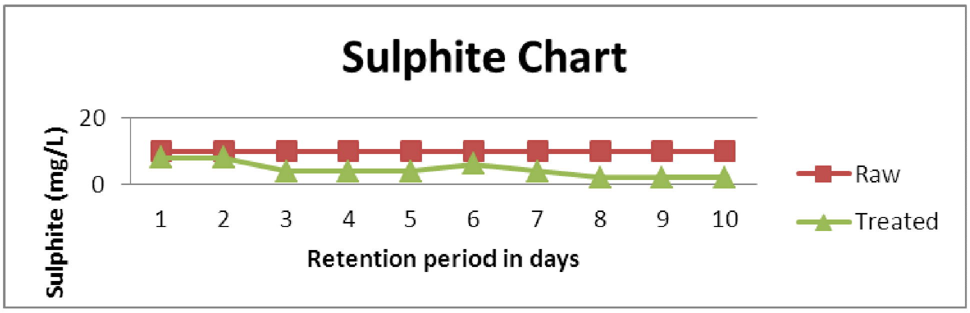


Figure 14: Chart of sulphite showing treated water against raw water with retention days

### *3.10 Chloride*

High concentrations of chloride in water are not known to be toxic to humans, the regulation of its concentration is mainly due to taste. It is essential to monitor chloride concentration in boiler systems to prevent damage of metal parts. In high levels, chloride can corrode stainless steel and be toxic to plant life. The chloride in the treated water sample ranged between 600 to 730 which is more than the WHO standard of 200mg/L. It can be concluded that to obtain a more reduction in the chloride value, longer retention days will be advised.

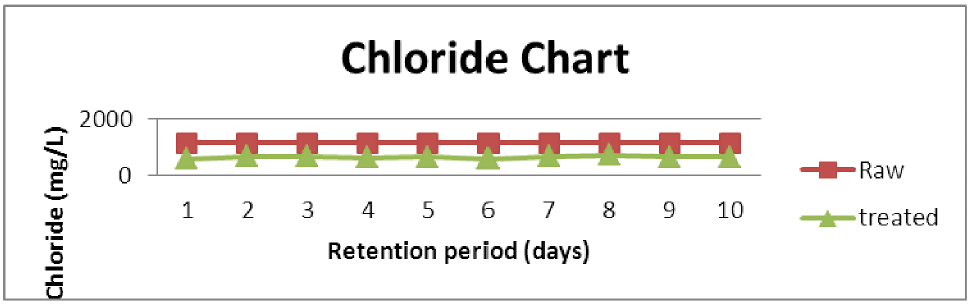


Figure 15: Chart of chloride showing treated water against raw water with retention days

### *3.11 Oxygen Reduction Potential*

Reduction potential is measured in volts (V), or millivolts (mV). Each water sample has its own intrinsic reduction potential; the more positive the potential, the greater the waters' affinity for electrons and tendency to be reduced. In aqueous solutions, the reduction potential is a measure of the tendency of the solution to either gain or lose electrons when it is subject to change by introduction of a new species.

 

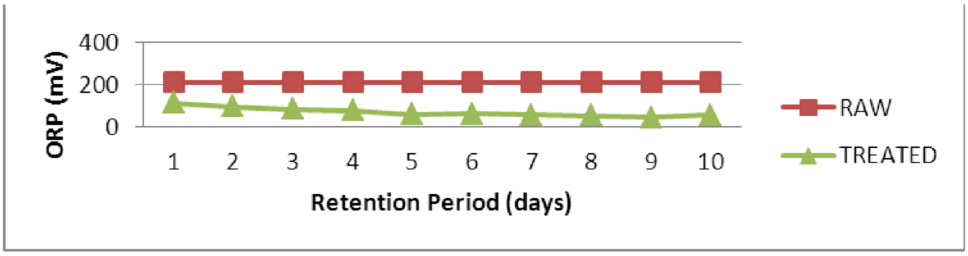


Figure 16: Chart of ORP showing treated water against raw water with retention days

### *3.12 Magnesium*

In concentration greater than 125 mg/L, magnesium can cause diuretic effects. Magnesium is also an important contributor to the hardness of water: when heated, magnesium salts break down forming incrustation in boilers. Moreover magnesium is necessary to plant metabolism since it is an essential constituent of organic molecules such as chlorophyll. In the analysis carried out, the value of magnesium ranged from 43.74 – 72.9, which falls lower than the NER standards for discharge of effluent into water.

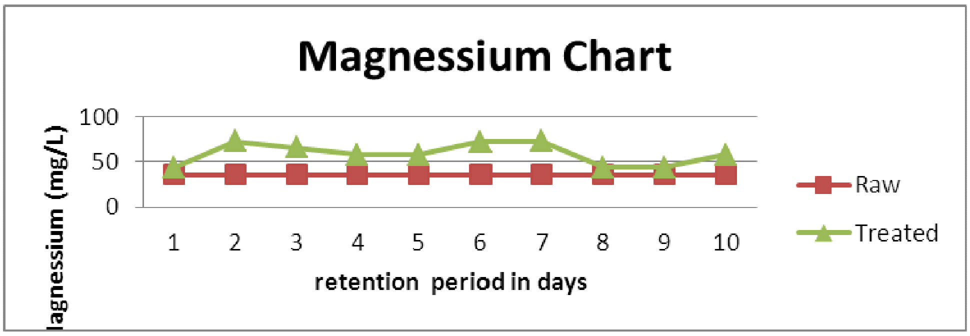


Figure 17: Chart of Magnesium showing treated water against raw water with retention days

### *3.13 Nitrate*

In this study, the nitrate-N concentrations ranged between 0-10mg/L and changed significantly. It is important to note that nitrate level in the stream could be a source of eutrophication for receiving water as the obtained values falls within the range recommended limit for FEPA. Excessive amounts can contribute to blue baby syndrome that affects the oxygen carrying capacity of infant's blood. Also known as methaemoglobinemia and also causes adult illness.

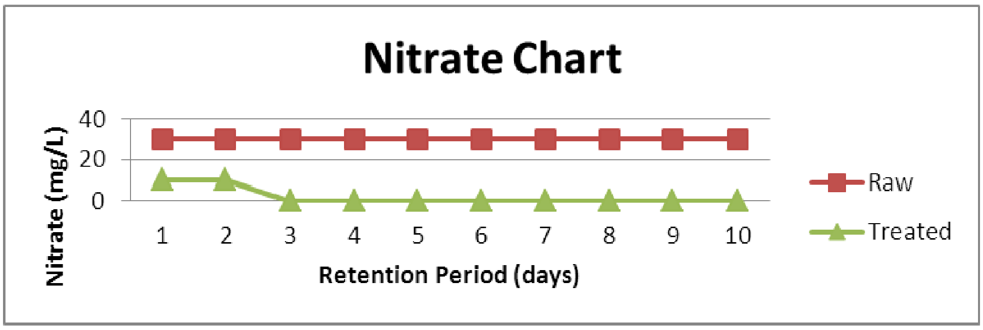


Figure 18: Chart of Nitrate showing treated water against raw water with retention days

 

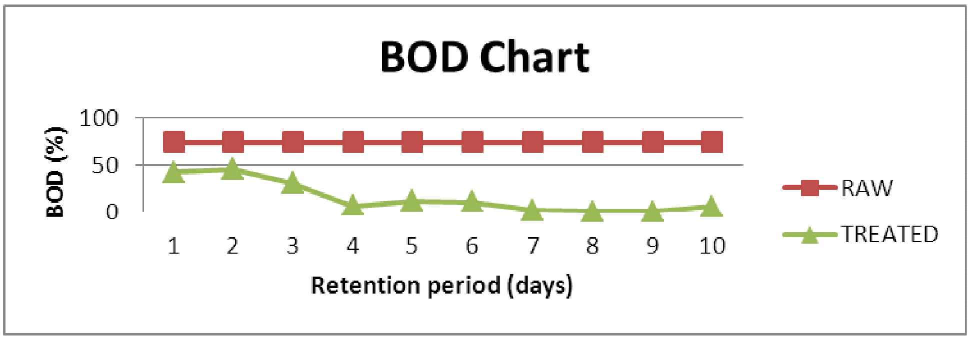

Figure 19: Chart of BOD showing treated water against raw water with retention days

### *3.14 Biological Oxygen Demand*

Biological Oxygen Demand (BOD) is the measure of the oxygen required by microorganisms whilst breaking down organic matter. From the analysis carried out there was gradual reduction in BOD and total removal on the 8th and 9th day. The range of the percentage removal is from 38.2% to 100%.

## 4. Conclusion and Recommendations

Based on the finds from this study, the following conclusions are drawn:
The free water Surface flow constructed wetland using common reed (Phragmites australis) is effective and suitable for treating domestic wastewater. A detention period of seven days is optimal for effective treatment of the collected wastewater from kitchen. The treatment system is a low cost and environmental friendly technique, and it is suitable for use at the very point where the wastewater is generated. The treated water may be suitable for non-drinking purposes such irrigation and fishery.

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